

the reel. The remaining portion of the curve shows that the EFL peaks at some point near the center of the tube length and then tapers off near the end of the tube winding.

This is a significant problem with long buffer tubes (approximately 10 km in length) and having a relatively small core radius for the take-up reel (around 100 mm). When the parabolic variation becomes too large the fiber attenuation near the middle of the length of the cable can be significant, thus making the cable useless.

An additional problem of the prior art methods of manufacturing buffer tubes is the limiting effect on the line speeds of the manufacturing process due to the uneven EFL distributions. As line speeds increase the EFL distribution problems become more significant. Therefore, to avoid these problems, manufacturing speeds are limited so as to prevent significant EFL problems.

### SUMMARY OF THE INVENTION

The present invention is directed to eliminating or greatly reducing the impact of the above problems by the use of prior art methods of manufacturing buffer tubes with optical fibers.

The present invention uses the variation of a number of different parameters or physical characteristics of the manufacturing process or equipment, either individually or in combination, to provide a substantially uniform EFL distribution along the entire length of a manufactured buffer tube. In a first embodiment of the present invention, a pad having a compliant stiffness is placed on the core of the take-up reel prior to the winding of the manufactured buffer tube, and the take-up tension of the tube as it is being drawn is monotonically decayed according to a set function so as to ensure an even EFL distribution along the entire length of the buffer tube. Although it is contemplated that the present

invention can provide an even EFL distribution without the use of a stiffness-compliant pad, it is to be used in the preferred embodiment to provide stress relief in the initial layers of the buffer tube, located closest to the core.

In a second embodiment of the present invention, a substantially even EFL

- 5 distribution is accomplished by using a combination of the stiffness compliant pad on the core of the reel with varying the angular speed of the take-up spool during the spooling of the buffer tube. Similar to the first embodiment, the variation in the speed of the take-up spool combined with the stiffness-compliant pad is used to provide a substantially even stress and strain distribution throughout the length of the tube, thus resulting in a substantially even EFL
- 10 distribution. As with the first embodiment, it is contemplated that only the variation in the angular speed of the take-up spool can be used to provide an even EFL distribution, but in the preferred embodiment the combination is to be used.

- In a third embodiment of the present invention, stiffness-compliant pads are placed between layers of tube windings at intervals throughout the reeling of the buffer tube, as well
- 15 as on the spool core. The use of these pads at intervals allow the excess stress and strain in the tubes and fibers to be absorbed in the pads. It is preferred, in this embodiment, that the use of the stiffness-compliant pads be combined with either varying the take-up tension or the angular speed of the spool, as discussed in the previous two embodiments. Further, in this embodiment, pads can be placed between each winding or at regular intervals in the tube
- 20 winding. Additionally, this embodiment can be used with a stiffness-compliant pad on the reel core, as described above. It is preferred in this embodiment, that the tubes be re-reeled after the initial reeling step and the tube is allowed to cool to room temperature to aid in

achieving a more uniform EFL distribution. The re-reeling step can be used with any of the above embodiments.

In the fourth embodiment, the layers are separated with rigid, preferably metal or composite cylindrical panels separating the layers and thus "breaking" up the stress compounding from upper layers. The panels can have slots to allow the tube to continue onto the next level.

It is to be noted that it is further contemplated that although the above embodiments can be used individually to obtain a substantially even EFL distribution, it is contemplated that any combination of the embodiments, or components thereof, can be used without altering the scope or spirit of the present invention. For instance, monotonically decaying the take-up tension may be combined with the varying of the angular spool speed and the use of stiffness-compliant pads or stiff cylindrical separators in the windings of the spool to achieve an even EFL distribution.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments of the invention which are schematically set forth in the drawings, in which:

Figure 1 is a graphical representation of a typical parabolic residual distribution of EFL along the length of a buffer tube;

Figure 2 is a graphical representation of the residual distribution of EFL along the length of a prior art buffer tube, along with a distribution of a buffer tube made in accordance with the present invention;

Figure 3 is a diagrammatical representation of a buffer tube manufacturing apparatus;